DOE Nuclear Physics Research, Facilities, Priorities, and Opportunities

RHIC/AGS User Meeting
June 9, 2022

Dr. Timothy J. Hallman
Associate Director of the Office of Science
for Nuclear Physics
DOE NP is a Primary Federal Steward of U.S. Nuclear Physics Research

DOE NP supports ~ 90% of the nation’s investment in basic research in nuclear physics in the U.S.

It is responsible for Strategic Planning, Funding, and Implementation

Goals and Deliverables:
- Knowledge
- Leadership class facilities
- New technology
- A highly-trained, diverse workforce capable of supporting DOE & other missions

U.S. science, commerce, medicine, defense—all benefit, in part, from a stable level of sustained competence, capability, capacity, and leadership in nuclear physics; DOE NP is the U.S. steward responsible for reliably delivering that benefit.

Where NP PHDs go

- Industry 24%
- Research Labs 27%
- University 26%
- Government 15%
- Finance 8%

U.S. DEPARTMENT OF
Office of Science

RHIC/AGS User Meeting

June 9, 2022
The vast range of time (μsec to 13.8B years) and physical scales (quarks to galaxies) requires “microscopes” and tools of varying resolving “power”
A Major Part of NP Stewardship is Operating:

Relativistic Heavy Ion Collider
Continuous Electron Beam Accelerator Facility
Argonne Tandem Linac System
Facility for Rare Isotope Beams

“Microscopes” of Varying Resolving Power
FY 2022 Highlight

Secretary Granholm at the FRIB Ribbon Cutting
May 2, 2022

FRIB Experiment E21062
Spokespersons: J. Allmond (ORNL), H. Crawford (LBNL), B. Crider (Mississippi State University), R. Grzywacz (University of Tennessee Knoxville) and V. Tripathi (Florida State University)

Department of Energy
Office of Science

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The High-Level DOE NP Work Plan

1. Operate and get science out from the Relativistic Heavy Ion Collider (RHIC), the Continuous Electron Beam Accelerator Facility (CEBAF), the Argonne Tandem Linac Accelerator System (ATLAS) and the Facility for Rare Isotope Beams (FRIB)

2. Make progress on a U.S.-led ton-scale neutrino-less double beta decay experiment.

3. Start construction of a high-energy high-luminosity polarized electron-ion collider (EIC)

4. Implement smaller scale instrumentation to take advantage of facility capabilities

The work plan centers on scientific discovery: to understand all forms of nuclear matter. The knowledge gained benefits energy, commerce, medicine, and national security.

Beginning preparations are getting underway for the next Long Range Plan Exercise
Recent Impactful Accomplishments

- Discovery that ionizing radiation reduces coherence time for entangled quantum states
  - Need new quantum materials or/and underground Quantum Computing

- First known observation of the Breit-Wheeler two-photon process at RHIC
  - Confirmation of Quantum Electro-Dynamic (QED) process; possibility of e+e- pair production via lasers

- Discovery that heavy nuclei have a neutron skin (CEBAF)
  - New constraints on neutron star radii and their equation of state

- Implementation of dynamical fermions and the real pion mass in Lattice QCD
  - Major advance in fidelity of Lattice Quantum Chromodynamics calculations

- Initiation of the FRIB science program
  - Opening a new frontier to understand heavy element production in cosmos

- Integration of AI technology at CEBAF to make it more fault tolerant
  - Test-bed for use of Artificial Intelligence in accelerator control and optimization
NP Participation in SC Initiatives

<table>
<thead>
<tr>
<th>SC/DOE Initiatives</th>
<th>FY21 Enacted</th>
<th>FY22 Enacted</th>
<th>FY23 PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantum Information Sciences (QIS)</td>
<td>13,347</td>
<td>10,866</td>
<td>10,866</td>
</tr>
<tr>
<td>Artificial Intelligence and Machine Learning (AI)</td>
<td>4,000</td>
<td>4,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Microelectronics</td>
<td>-</td>
<td>518</td>
<td>518</td>
</tr>
<tr>
<td>Strategic Accelerator Science and Technology Initiative</td>
<td>-</td>
<td>1,037</td>
<td>-</td>
</tr>
<tr>
<td>Reaching a New Energy Sciences Workforce (RENEW)</td>
<td>-</td>
<td>3,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Funding for Accelerated, Inclusive Research (FAIR)</td>
<td>-</td>
<td>-</td>
<td>2,000</td>
</tr>
<tr>
<td>Accelerate Innovations in Emerging Technologies</td>
<td>-</td>
<td>-</td>
<td>4,000</td>
</tr>
</tbody>
</table>

Scientific Discovery Through Advanced Computing $ 2,878 $ 3,543 $ 3,494

NP is also cultivating the possibility of a symbiosis with NIH to spark a significant advance in imaging useful for both DOE and NIH research
Recent Ops increases largely due to bringing FRIB online and making reliability upgrades at CEBAF.
## NP Projects: Status and Operations Plan

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Status</th>
<th>Cost</th>
<th>CPI</th>
<th>SPI</th>
<th>CD-4</th>
<th>Operation cost plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction Projects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility for Rare Isotope Beams (FRIB)</td>
<td>MSU</td>
<td>CD-4</td>
<td>$730M</td>
<td>1.00</td>
<td>1.00</td>
<td>6/2022</td>
<td>Included in NP budget formulation</td>
</tr>
<tr>
<td>Electron-Ion Collider (EIC)</td>
<td>BNL</td>
<td>CD-1</td>
<td>$1.7B to $2.8B</td>
<td></td>
<td></td>
<td></td>
<td>RHIC operations funds redirected to EIC project recovered for EIC operations</td>
</tr>
<tr>
<td><strong>Major Items of Equipment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Gamma Ray Energy Tracking Array (GRETA)</td>
<td>LBNL</td>
<td>CD-2/3</td>
<td>$58.3M</td>
<td>0.98</td>
<td>0.94</td>
<td>4/2028</td>
<td>Mostly covered by host laboratory operations experimental support</td>
</tr>
<tr>
<td>Super Pioneering High Energy Nuclear Interaction Experiment (sPHENIX)*</td>
<td>BNL</td>
<td>PD-3</td>
<td>$27.0M</td>
<td>1.02</td>
<td>0.85</td>
<td>12/2022</td>
<td>Covered by RHIC operations experimental support</td>
</tr>
<tr>
<td>Measurement of Lepton-Lepton Electroweak Reactions (MOLLER)</td>
<td>TJNAF</td>
<td>CD-1</td>
<td>$45.8M to $56.6M</td>
<td></td>
<td></td>
<td></td>
<td>Covered by TJNAF operations experimental support</td>
</tr>
<tr>
<td>High Rigidity Spectrometer (HRS)</td>
<td>MSU</td>
<td>CD-1</td>
<td>$85.0M to $111.4M</td>
<td></td>
<td></td>
<td></td>
<td>Covered by FRIB operations experimental support</td>
</tr>
<tr>
<td>Ton Scale Neutrinoless Double Beta Decay (TS-NLDBD)</td>
<td>TBD</td>
<td>CD-0</td>
<td>$215M to $250M</td>
<td></td>
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</tr>
</tbody>
</table>

Blue indicates “Completed”
In the Future Plan, RHIC Completes its Mission and the EIC is Built

CD-1 was attained in June 2021.

- Located at BNL and with TJNAF as a major partner. Estimated cost between $1.7 and $2.8 billion.
- Utilizes existing RHIC assets; adds electron storage ring, & electron cooling

NAS: A US-based EIC will uniquely answer

- How does the mass of the nucleon arise?
- How does the spin of the nucleon arise?
- What are the emergent properties of dense systems of gluons?”

The international community is already highly engaged with 1110 collaborators, from 32 countries, and 235 institutions actively working on EIC development.

EIC Dedication
The Global Campaign to Determine the Fundamental Nature of the Neutrino

The Search for Neutrino-less Double Beta Decay ($0\nu\beta\beta$): in a selected nucleus, two neutrons decay into two protons and two electrons, with no neutrinos being emitted.

It required the two neutrinos from the two $W^-$ particles to annihilate, proving the neutrino is its own anti-particle.

Three Proposed Technologies
- Scintillating bolometry (CUPID, $^{100}$Mo enriched Li$_2$Mo$_4$ crystals)
- Enriched $^{76}$Ge crystals (LEGEND-1000, drifted charge, point contact detectors)
- Liquid Xenon TPC (nEXO, light via SiPM, drifted ionization)

Potential Partners: Italy, Canada, and Germany
The NP Line of Sight to Broader Impacts & Other Missions

NP is providing new and updated nuclear data to existing “customers”
- Working to identify impactful nuclear data needs and leverage resources
  - Ex: Advanced Reactors with DOE/NE, ARPA-E

NP is reaching out to new nuclear data application customers
- Electronics protection (NASA, Missile Defense Agency, Federal Aviation Administration)
- Human safety (NASA [spaceflight], NIH [ion beam therapy])
- Advanced reactors (ARPA-E, NASA)

NP is exploring a mechanism for Rapid Response Nuclear Data
- Many federal agencies have projects with nuclear data shortfalls
- Project funding / scope does not cover nuclear data activities
- USNDP is investigating a process where performers can submit requests for urgent, high impact nuclear data needs

NP Leads a Nuclear Data Interagency Working Group (NDIAWG) that published 4 FOAs
NP Traineeships: 36 Proposals Resulting in 110 Traineeships

NP traineeship award recipients include:
- 18 MSIs,
- 10 other colleges/universities,
- 5 DOE laboratories

MSI award recipient distinctions:
- 9 Hispanic Serving Institutions (HSIs),
- 8 HBCUs,
- 5 Asian American, Native American, and Pacific Islander Serving Institutions (AANAPISI),
- 1 Predominantly Black Institution (PBI)

All other institutions on the map are involved in the traineeship program as recruitment sites (38), Co-Is (9), members of INSIGHT (8), and/or hosts (7)

40% of trainees identify as Hispanic
40% of trainees identify as Black or African American
10% of trainees identify as White
10% of trainees identify as other
Additional NP Traineeship and DEI Information

The INSIGHT team (left to right): Paul Gueye (MSU), Felecia Commodore (ODU), Geraldine Cochran (Rutgers), responsible to:

- Assess effectiveness
- Facilitate communication and coordination
- Survey to ascertain criteria related to retention
- Gather data for input to SC

Very strong statements by NP AD in community forums (APD/DNP Meetings) that the SC Statement of Commitment will be respected in the NP Community and that unwanted or abusive behavior, WILL STOP NOW.

Planned focus of FY 2023 RENEW investment: vehicle(s) for anchoring sustained investment at HBCUs and MSIs in technical areas important for SC (e.g. imaging, cryogenics) to “uptake” and retain talented trainees
The FY 2022 Enacted required large increases over FY2021 Enacted $728M vs $635M (+93M )

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPP Plan at JLAB</td>
<td>$6M</td>
</tr>
<tr>
<td>Weeks at JLAB</td>
<td>$19M</td>
</tr>
<tr>
<td>EIC</td>
<td>$20M</td>
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<tr>
<td>Core Research</td>
<td>$12.7M</td>
</tr>
<tr>
<td>FRIB Ops</td>
<td>$27M</td>
</tr>
<tr>
<td>Nuclear Data</td>
<td>$2.8M</td>
</tr>
<tr>
<td>RENEW</td>
<td>$3.0M</td>
</tr>
<tr>
<td>Initiatives</td>
<td>$2.5M</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$93M</strong></td>
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## NP FY2022 Enacted and FY2023 PR

<table>
<thead>
<tr>
<th>Category</th>
<th>FY22 Enacted</th>
<th>FY23 PR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium Energy</strong></td>
<td>$196.1 M</td>
<td>$193.7 M</td>
</tr>
<tr>
<td>CEBAF Ops</td>
<td>$142.7 M</td>
<td>$143.4 M</td>
</tr>
<tr>
<td>Research</td>
<td>$53.4 M</td>
<td>$50.3 M</td>
</tr>
<tr>
<td><strong>Heavy Ion</strong></td>
<td>$255.5 M</td>
<td>$245.0 M</td>
</tr>
<tr>
<td>RHIC Ops</td>
<td>$183.9 M</td>
<td>$191.8 M</td>
</tr>
<tr>
<td>Research</td>
<td>$46.5 M</td>
<td>$43.2 M</td>
</tr>
<tr>
<td>Project</td>
<td>$25.0 M</td>
<td>$10.0 M</td>
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<tr>
<td><strong>Low Energy</strong></td>
<td>$199.1 M</td>
<td>$217.5 M</td>
</tr>
<tr>
<td>FRIB, ATLAS Ops</td>
<td>$107.8 M</td>
<td>$125.5 M</td>
</tr>
<tr>
<td>Research</td>
<td>$73.9 M</td>
<td>$68.1 M</td>
</tr>
<tr>
<td>Projects</td>
<td>$17.4 M</td>
<td>$23.9 M</td>
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<tr>
<td><strong>Theory</strong></td>
<td>$57.3 M</td>
<td>$63.0 M</td>
</tr>
<tr>
<td>Research</td>
<td>$57.3 M</td>
<td>$63.0 M</td>
</tr>
<tr>
<td><strong>Facility Construction</strong></td>
<td>$20.0 M</td>
<td>$20.0 M</td>
</tr>
<tr>
<td>EIC</td>
<td>$20.0 M</td>
<td>$20.0 M</td>
</tr>
<tr>
<td><strong>Total, NP</strong></td>
<td>$728.0 M</td>
<td>$739.2 M</td>
</tr>
</tbody>
</table>

Targeted increases are made in the FY 2023 Request compared to FY 2022 Enacted $739.2M vs $728M (+11.2M)

- FRIB Ops $15.8M
- GRETA $6.5M
- AI/ML $4M
- RENEW $3M
- FAIR Initiative $2M
- Accelerate Innovation $4M

Funds to support targeted increases above the overall NP increase come from the NP base.
FY 2023 Request Highlights - NP

- FRIB begins its first full year of science research studying atomic number 28 nuclei near the limit for nuclear existence

- NP User Facilities (RHIC, CEBAF, ATLAS, and FRIB) all operate at or above 90% utilization

- The Electron-Ion Collider “memorializes” international in-kind contributions as part of finalizing preparations for CD-2 Review, Approve Performance Baseline. EIC A/E design is begun.

- sPHENIX begins science research at RHIC to determine the novel properties of the quark-gluon plasma

- LEGEND-200 begins initial search for new physics via the slowest rare decay ever attempted

- Funding for the Gamma Ray Energy Tracking Array (GRETA) MIE is in accordance with technically driven schedule

- NP investment in the AI/ML cross-cutting research and RENEW doubles

- NP participates in the new cross-cutting initiatives in Funding for Accelerated Inclusive Research (FAIR) and Accelerate Innovations in Emerging Technologies (Accelerate)
DOE Office of Nuclear Physics

Timothy J. Hallman, Associate Director
Melissa Emerson, Administrative Specialist (CONTR)

Physics Research Division
VACANT, Director
Christine Izzo, Program Support Specialist

Medium Energy & Quantum Information Science
Gulshan Rai, Technical Advisor
Spyridon Margetis (IPA)

Heavy Ion Nuclear Physics
Kenneth Hicks

Nuclear Structure and Nuclear Astrophysics
Sharon Stephenson
Kelsie Krafton (AAAS Fellow)

Nuclear Theory
Astrid Morreale, Acting
VACANT

Nuclear Data
Keith Jankowski

Fundamental Symmetries
Paul Sorensen

Nuclear Physics Computing
Xiaofeng Guo

Research Division
8 Feds
1 IPAs
1 AAAS fellow
1 Acting
2 vacancies
FY 22 Enacted: $231.1M

Associate Director’s Office Staff
Brian Knesel, Financial Management Specialist
Dannette Keen, Financial Management Analyst
Linnette Quick, Program Assistant (CONTR)
Brenda May, Program Analyst
Michael Famiano, International Cooperation and Outreach

Facilities & Project Management Division
VACANT, Director
Jehanne Gillo (Acting)
Saryna Cameron, Program Support Specialist (CONTR)
Paul Mantica (IPA), Technical Advisor
Latifa Elouadrhiri (Detailee)

Advanced Technology R&D
Manouchehr Farkhondeh, Deputy

Nuclear Physics Facilities
James Sowinski

Nuclear Physics Major Initiatives
Ivan Graff

Nuclear Physics Instrumentation
Elizabeth Bartosz

Industrial Concepts
Michelle Shinn

Facilities & Projects Division
5 Feds
1 IPAs
2 Contractors
1 Acting
1 vacancy
FY 22 Enacted: $496.9M

(dpa) – Intergovernmental Personnel Act
Other news

• Charge on Nuclear Data presented at the NSAC Meeting, April 20, 2022 (Virtual)

• Plan for the charge for the next LRP to be delivered at the following NSAC meeting July 13, 2022 (Hybrid Meeting).

• Ken Hicks is officially a Fed responsible for Heavy Ion Physics

• Astrid Morreale is now Acting PM for Nuclear Theory

• Paul Mantica is an IPA in charge of Facilities and Projects Division

• David Cinabro joins NP as a Fed to steward NP Facilities

• Michael Famiano joins NP as a Fed to help steward outreach and international collaboration

• Spiros Margetis is an IPA assisting Gulshan Rai with Medium Energy

• Dannette Keane is a new NP budget analyst with a primary focus on execution

• Melissa Emerson is the new administrative support person for the Associate Director

• Saryna Cameron is the new support person for the Facilities and Projects Division

• Kelsie Krafton is an AAAS Fellow stewarding DEI efforts in NP

• In general NP staff are “back in the office” with modified in-person schedules

• Based on lessons learned from the pandemic Fed travel will likely be reduced, in-person office presence will be reduced, remote work and telework will be more common. DOE supported travel is slowly opening back up but is halted once again to areas experiencing high transmission. Masks are optional.
There has been a long tradition in Nuclear Science of effective partnership between the community and the agencies in charting compelling scientific visions for the future of nuclear science.

Key factors:

1) Informed scientific knowledge as the basis for recommendations and next steps

2) Mutual respect among scientific sub-disciplines

3) Commitment to the greater good of nuclear science as a discipline

4) Meticulously level playing field leading to respect for process and outcomes

5) Deep appreciation for the wisdom of Ben Franklin

Staying united we can accomplish great things together

Division will setback the entire field and is the last thing needed right now